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Part I The Distribution and Depuration of Kepone in American Eels, Anguilla Rostrate, from the James River, Virginia Part II An Economic Analysis of the Commerical Depuration of Kepone contaminated American Eels, Anguilla rostrata, from the James River, Virginia

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PART I

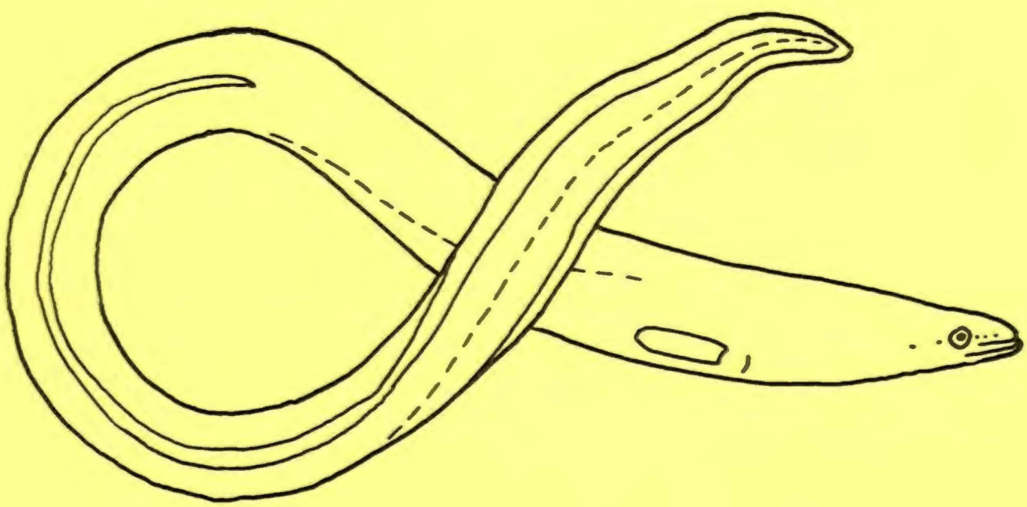
THE DISTRIBUTION AND DEPURATION OF KEPONE IN AMERICAN EELS, *ANGUILLA ROSTRATA*, FROM THE JAMES RIVER, VIRGINIA

By Marion Y. Hedgepeth and Linda L. Stehlik

PART II

AN ECONOMIC ANALYSIS OF THE COMMERCIAL DEPURATION OF KEPONE CONTAMINATED AMERICAN EELS, *ANGUILLA ROSTRATA*, FROM THE JAMES RIVER, VIRGINIA

By Charles C. Sharman, Jr.



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Part I

THE DISTRIBUTION AND DEPURATION OF KEPONE IN AMERICAN EELS, *ANQUILLA ROSTRATA*, FROM THE JAMES RIVER, VIRGINIA.

by

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TABLE OF CONTENTS PAGE

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This research was conducted at the Virginia Institute of Marine Science with financial support recieved through the Commonwealth of Virginia from funds endowed to the state by Allied Chemical, Inc. for the purposes of Kepone research.

We wish to thank Drs. J. V. Merriner, H. M. Austin and M. E. Bender for reviewing this report. Also, we gratefully acknowledge the art work of Mary Ann Vaden and the typing of the report by Nancy Peters.

INTRODUCTION

Kepone is an insecticide developed by Allied Chemical Company in the early 1950's. It is a member of the cyclodiene insecticide family which includes Mirex, Aldrin, Dieldrin, Heptachlor and several other less-known pesticides. Kepone was principally utilized in Central America on banana root borers and in Europe where it was converted to other pesticide products. In the United States, limited quantities were incorporated into ant and roach traps for commercial sale.

Kepone is the tradename for chlordecone. Chlordecone was manufactured only in Hopewell, Virginia by Allied's Semi Works Plant from 1963 through early 1975 and by Life Science Products Company from 1974 through early 1975.

Environmental contamination in the Hopewell area was first suspected in October and December of 1974 during an investigation of the Life Science Products Company by staff members of the Virginia State Water Control Board and State Department of Health. In 1975, an inspection of the upper tidal James River by the United States Environmental Protection Agency revealed that Kepone was present in the air, soil and waters around the city of Hopewell. Subsequent studies showed that Kepone was detectable in the biota of the James River System. As a result the James River System was closed to commercial finfishing (with the exceptions of channel catfish and American shad) in early 1976. In addition, the United States Food and Drug Administration established an action level of 0.3 ppm of Kepone in finfishes utilized for human consumption.

In 1977, the Virginia Institute of Marine Science (VIMS) began studies on the rates of Kepone elimination in finfish species which migrate from the James River during some period of their life cycle. Laboratory studies were conducted on Atlantic croaker, *Micropogonias undulatus*, (Doyle et al., in press) and Spot, *Leiostomus xanthurus*, (Hedgepeth et al, 1978) collected from the James River Doyle et al. noted a significant drop in the Kepone concentration of Atlantic croakers held in Kepone-free York River water for 24 weeks (168 days). This change in mean residue levels coincided with a rise in the ambient water temperature to above 15°C. Therefore, it was concluded that natural adult populations returning to the James from the south may be able to depurate the majority of Kepone from their tissue. A mean loss in Kepone residue of 72 percent was observed in Spot held for a period of 200 days in Kepone free water; however, only 30 percent of the fish utilized in the test had Kepone concentrations below the established action level for human consumption.

In this study, American eels, *Anguilla rostrata*, from the James River were used as the test species. Eels of the genus *Anguilla* are catadromous finfish which spawn out at sea, but spend the majority of their life cycle in the fresh and brackish waters of coastal regions. Prior to the closing of the tidal James River in 1976, American eels were reportedly very plentiful and were sold at generally good prices. A detailed discussion of the economic importance of American eels is included in Part II of this report.

Because of their wide distribution and the minimal amount of care required to maintain them, Anguillid eels are being used more frequently today in pesticide and heavy metal research. Also because of their relatively high fat content compared to other teleosts Anguillid eels are useful indicator species for pesticide contamination in their freshwater and estuarine habitats. Holmberg et al (1972) studied the metabolic effects of technical pentachlorophenol (PCP), a fungicide and molluscicide, on the eel *Anguilla anguilla*; while Janicki et al (1976) observed the metabolic effects of DDT, an insecticide, on *A. rostrata*. In heavy metal research, Anguillid eels have been utilized in laboratory analysis of the short and long term effects of exposure to cadmium and mercury (Noel-Lambot et al 1977) and of uptake and excretion of radioactive chromium (von Fouquier et al, 1973).

MATERIALS AND METHODS

Fish Collection

For the 1978 study, approximately 60 marketable-size (from 342-601 mm in total length to 104-380 g in total weight) American eels were collected in eel pots on September 9, 1978, from mile 50 of the James River (about 12 miles below Hopewell, Virginia). Approximately 100 eels were obtained on May 11, 1979, from the same general area for the 1979 study. These eels ranged in size from 330-840 mm in total length to 65-953 g in total weight. In both experiments, the eels were transported back to VIMS and put in a 180 gallon (581 liter) circular fiberglass tank supplied with Kepone-free fresh water and aeration (Fig. 1). The eels were not fed at any time. Water temperature in both experiments ranged between 17-20°C.

In the 1978 study ten eels were anesthetized with tricaine methane sulfonate (MS-222) and sacrificed on days 0, 7, 14, 21 and 49. In the 1979 study ten eels were anesthetized and sacrificed on days 0, 14, 28, 42, 56 and 70. Before the actual chemical analysis for Kepone:
(1) Otoliths were removed and placed in glycerin for later age determination (number of years in fresh water); (2) a portion of the gonad was removed for histological determination of sex; (3) a small portion of the liver was removed for histological observations, while the remaining portion was removed, weighed, and stored for Kepone analysis; (4) and finally, the eels were gutted, skinned and cleaned so that only the edible

meat portion remained. In the 1979 study, samples of adipose fat, gonad tissue, and gallbladders (bile material) were taken periodically for Kepone analysis. Also, general observations of lesions or sores, parasites and other physical disorders were recorded.

Effluent Analysis

It is very difficult to detect Kepone in the water column; since Kepone is not readily soluble in water. Consequently, in the 1979 study we chose to determine Kepone effluent levels by exposing a filter-feeding organism to water that had been utilized by the contaminated eels. On May 25, 1979, 21 wedge clams, *Rangia cuneata*, (between 50-60 mm in diameter) were collected from the Rappahannock River just above Tappahannock, Virginia. Seventeen of the *Rangia* were placed in an aquarium which received water flowing out of the eel tank. The remaining four clams were analyzed for Kepone to verify that they were uncontaminated. Thereafter, biweekly samples of four or five *Rangia* were sacrificed for Kepone analysis.

Chemical Analysis

Edible meat samples from eels were ground in a meat grinder into hamburger consistency and frozen at -5°C for 24 hours to rupture the cells and then thawed. Composite samples consisted of three grams of meat from each of the ten eels sacrificed during a given period. Liver, fat, gonad and gallbladder tissue were weighed, chopped, and frozen. If individual eels had small amounts of fat a composite fat sample was run. After thawing, a mixture of anhydrous sodium sulfate and Quso[R] G-30 (precipitated silica, Philadelphia Quartz Co.) was added for desiccation. The proportions of sample to the desiccants were: 30 g fish - 54 g $NA_2 SO_4$ - 6 g Quso. The samples were taken, mixed, and refrozen. After thawing the desiccated samples were ground with a blender to a powdery consistency and transferred to pre-extracted paper thimbles for Soxhlet extraction. Extraction was carried out using 1:1 ethyl ether-petroleum ether for 16 hrs. Extracts were then concentrated by evaporation and cleaned by activated fluorisil column chromatography (EPA, 1975). The Kepone containing elutriate was analyzed by electron capture gas chromatography utilizing packed columns with one or more of the following liquid phases: 4% SE-30 + 6% OV 210; 1.5% OV-17 + 1.95% QF-1 + 3% OV-1.

Histological Analysis

Samples of gonad and liver tissue from the eels were preserved in Bouin's fixative. Sectioned tissues were stained in a modified Harris hematoxylin and eosin Y. Observations on the sex and stage of gonadal development were recorded. General comments were made on the condition of the liver tissues. At the end of the study comparisons were made between livers of the contaminated eels and livers removed from eels captured during July of 1979 from the Rappahannock River.

Statistical Analysis

All computations were generated with the Statistical Package for the Social Sciences (SPSS, Nie et al., 1975).

Bartletts Test for Homogeneity, Student Newman-Keuls Test and Pearson's correlation coefficients were used to demonstrate any relationships that existed between variables.

RESULTS

Edible Meat

In the 1978 study, the concentration of Kepone in the edible meat samples which initially averaged 0.728 ppm decreased to an average of 0.080 ppm of Kepone after 49 days in Kepone-free water (Fig. 2 and Table 1). A Pearson correlation coefficient of -0.6256 ($p = .001$) demonstrated that a negative relationship existed between the Kepone concentrations in the eels and the number of days they were allowed to depurate. No significant relationships were observed between the Kepone concentration of an eel and the length, weight, sex, gonad condition or age. Significant weight losses or size differences were not apparent in either the 1978 or 1979 studies (Table 2).

An analysis of variance confirmed the fact that most of the variance in Kepone concentration was a factor of the number of days in Kepone-free water (Table 3). Three homogenous subsets were created in a Student-Newman-Kuels Test (SNK) utilizing the two variables Kepone concentration (in parts per million, ppm) and Time (in days). The difference in the concentrations of day 49 eels was attributed to the elimination of Kepone from the muscle tissues; while the rise in the concentrations of day 14 eels was possibly attributed to a random selection of highly contaminated eels and/or to sudden redistribution of Kepone-laden mesenteric fat or the reabsorption of gonad tissues to the muscle tissues as a result of starvation.

In the 1979 study a Kepone analysis of the initial sample disclosed a mean Kepone concentration of 0.575 ppm in the edible meat portions. Edible meat samples of days 14, 28, 42 and 70 contained about the same concentration of Kepone (0.5 ppm); therefore, only one homogenous subset was found in a SNK analysis. Eels taken on day 56 showed the greatest deviation ($\bar{X}$ = 0.277 ppm) from the initial sample (Fig. 2 and Table 1). Thus in the 1979 study, the eels did not depurate a significant amount of Kepone over the test period of 70 days.

Liver and Gallbladder

Only livers from eels of dsy 49 were examined for Kepone in the 1978 study (Table 1). Although Kepone concentrations in the edible meat portions of day 49 were low, corresponding concentrations in their livers were high ($\bar{X}$ = 2.82 ppm). Thus, it appeared that the liver was operative in the elimination or possible detoxification of Kepone from the muscle tissues.

Kepone concentrations in the livers of the 1979 initial sample varied considerably (0.26 ppm to 6.0 ppm). During the study, a positive Pearson correlation coefficient of 0.51 (P - .001) was observed for the relationship between the Kepone concentrations in the edible meat samples and in the liver samples (Fig. 3). Histological examination of the eel livers revealed large areas of extensive vacuolation; however, areas of extensive vacuolation were also observed in liver samples taken from eels collected for comparison from the Rappahannock River. In both cases this signified a decrease in the number of hepatic cells present in the liver and possible malfunctioning of the organ. This may have been caused by any number of reasons including starvation and other stresses. Therefore these observations were not attributed to the concentration of Kepone present in the liver at the time of sacrifice.

A significant increase in the size of the gallbladder in some eels was noted from day 42 through day 70. A comparison between the average size of a gallbladder of a Rappahannock eel and an eel from day 70 is shown in Figure 4. Note that in Figure 4A the liver was pushed aside for the gallbladder to be shown. Kepone analysis of a composite gallbladder sample of day 70 eels demonstrated that Kepone was present in relatively high levels in the bile material (0.9 ppm) as compared with the edible meat, liver and fat samples of that period (Fig. 3). Likewise, Egle et al. (1975) found the greatest amount of radioactive ^{14}Kepone in the bile of experimental rats followed in decreasing magnitude by blood, liver, feces, kidney, urine and spleen.

Mesenteric Fat and Gonad Tissue

Kepone concentrations in fat samples were generally lower than corresponding edible meat and liver samples throughout the 1979 study (Fig. 3 and Table 1); while only a slight correlation was observed between gonad samples and edible meat and liver samples.

<u>Effluent</u>

Kepone-free wedge clams, *Rangia cuneata*, accumulated Kepone from the eels at constantly increasing concentrations over a period of 56 days of exposure (Fig. 5). A Kepone concentration of 0.06 ppm was found in the clams after 11 days of exposure; while, a Kepone concentration of 0.11 ppm was observed in clams sacrificied after 56 days of exposure (day 70 of the eel depuration period). Similarly, Haven et al., (1977) observed that *Rangia* accumulated Kepone from undisturbed sediments to a high of 0.05 ppm after a week; while, *Rangia* exposed to Kepone in suspended particle accumulated slightly more. A gradual decrease to 0.03 ppm was observed in their study after four weeks.

DISCUSSION AND CONCLUSIONS

Ninety percent of the eels from day 49 of the 1978 study were well below the EPA action level of 0.30 ppm of Kepone in finfish for human consumption. Eels sacrificied after 49 days in Kepone-free water contained an average Kepone concentration of 0.080 ppm in edible meat tissues and 2.82 ppm in liver tissues. Similarly after exposing A. anguilla to 0.1 ppm of pentachlorophenol (PCP), Holmberg (1972) noted that treated eels held about 1.2 ppm in their liver and 0.08 ppm in their muscle tissue after 55 days of recovery. Retention of the pesticide was attributed to the possible high binding capacity of PCP to mitochondrial proteins and to the possible gradual release of accumulated PCP from lipid stores when the eels had to use lipids during the long starvation period. Therefore, PCP was redistributed to the liver after the initial uptake and accumulation periods. Thus in the 1978 study, Kepone may have been eliminated from edible meat samples (muscle tissue) as a result of the redistibution and utilization of lipid material during starvation.

Further studies are needed on the effects of lipid composition and metabolism on pesticide contamination. Love (1970) suggested that there may be a factor of selectivity by the fish in utilizing its lipid stores. For example, Dave et al. (1974) found that silver eels showed an enhanced redistribution and utilization of fat as well as carbohydrate and protein metabolism. In another study, Inui and Ohshima (1966) showed that of the three energy reserves (glycogen, lipid and proteins) *A. japonica* utilized the fat and glycogen in the liver during particularly the early periods of starvation. In fact, it was suggested that glycogen reserves might be depleted within a period of 15 days of starvation. On the other hand, Larsson and Lewander (1973) observed a marked decrease in liver glycogen during a later phase of starvation (between days 95 and 145); while, glycogen content in the muscle tissues remained relatively constant throughout the entire starvation period. Consequently, they suggested that the starving eels were more dependant on lipid reserves after the first three months. Thus, pesticide elimination in fishes will be a function of the metabolic rates and the specific binding capacity of the pesticide.

In the 1979 study, edible meat samples of days 14, 28, 42 and 70 contained about the same concentration of Kepone. Only samples taken on day 56 showed any significant change in Kepone concentration. Therefore, the eels did not depurate a significant amount of Kepone over a period of 70 days; however, it was demonstrated that Kepone was present in the water of the eel tank. Wedge clams, *Rangia cuneata*, collected from the Rappahannock River and shown to be Kepone-free accumulated Kepone at low levels from water that had been circulated through the eel tank. Thus, the wedge clams were bioconcentrating the small amounts of Kepone that were available to their tissues.

Some possible explanations can be given for the lack of Kepone depuration in the eels of the 1979 study. Approximately one month after the study was begun, many of the eels began to display sores over their bodies. The head region appeared to be the most frequently attacked area. The sores continued to get worse. Eels that were infected appeared to be in poor physical condition. In some cases the upper and lower jaws had all most completely rotted away. An examination by a VIMS parasitologist of a very sick eel on day 74 revealed that a myxobacterium was present in the lesions. Other bacteria were also present in smears of the lesions. Trypanosomes were also found in blood samples. This eel also possessed a large lesion that stretched across both lobes of the liver. Histological examination of the liver revealed that the bacterium was not present among the hepatic cells; however, there was noticable degeneration of the liver consisting of vacuolation and necrosis. The bacterial infection apparently spread among the eels quite extensively as a result of confinement, starvation and water temperatures. The bacterial infection may have affected metabolic processes in the eels while lowering their physical condition. Liver malfunctions may have altered the rate of Kepone elimination from tissues in the eels; thus, Kepone could not be removed from contaminated tissues.

If the risk of another bacterial infection among collections of eels could be eliminated, these fish would depurate Kepone from edible meat tissues to well below the EPA Action Level and in a commercially feasible amount of time (as demonstrated in the 1978 study). Now, chemicals such as copper sulfate and

Terramycin which are used to treat fish for bacterial infections, have been registered for use on food fish (Schnick and Meyers, 1978). Thus, we conclude that it is biologically feasible to reduce Kepone from the edible portions of American eels by holding them in Kepone free water.

SUMMARY

1. In the 1978 study, American eels depurated Kepone from edible meat tissues to almost nondetectable levels in 49 days.
2. In the 1979 study, Kepone concentrations in edible meat tissues remained relatively constant. This was attributed to the poor physical condition of the eels as a result of an extensive myxobacterial infection that occurred during the study.
3. Kepone-free wedge clams, *Rangia cuneata*, accumulated Kepone in low concentrations over an exposure period of 56 days during the 1979 eel depuration study.
4. High concentrations of Kepone were found in the gallbladders and livers of the eels.

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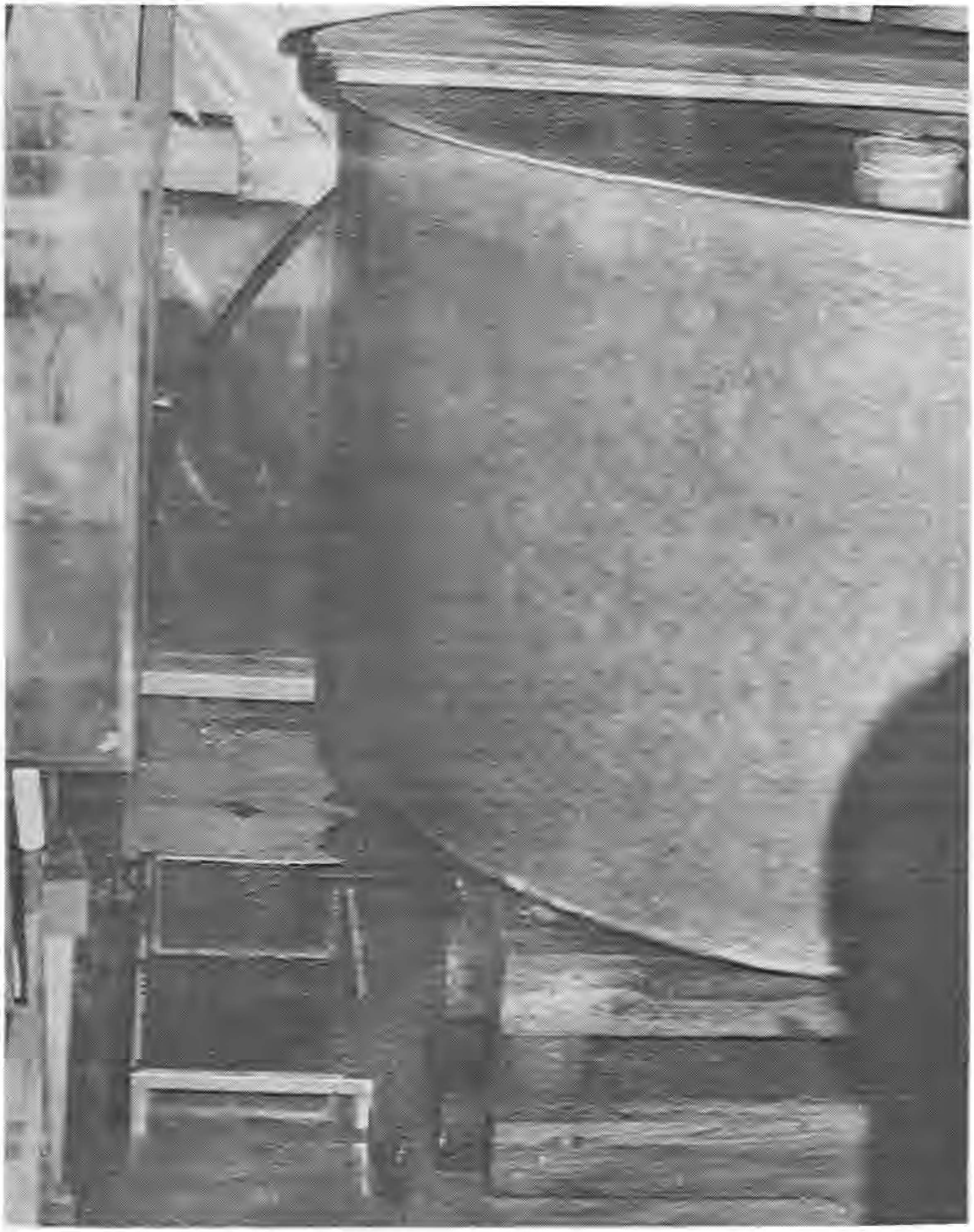


Figure 1. Experimental eel tank and aquarium containing <u>Rangia</u>.

Figure 2. Kepone concentrations (in ppm) in American eels from the 1978 and 1979 Depuration Studies.

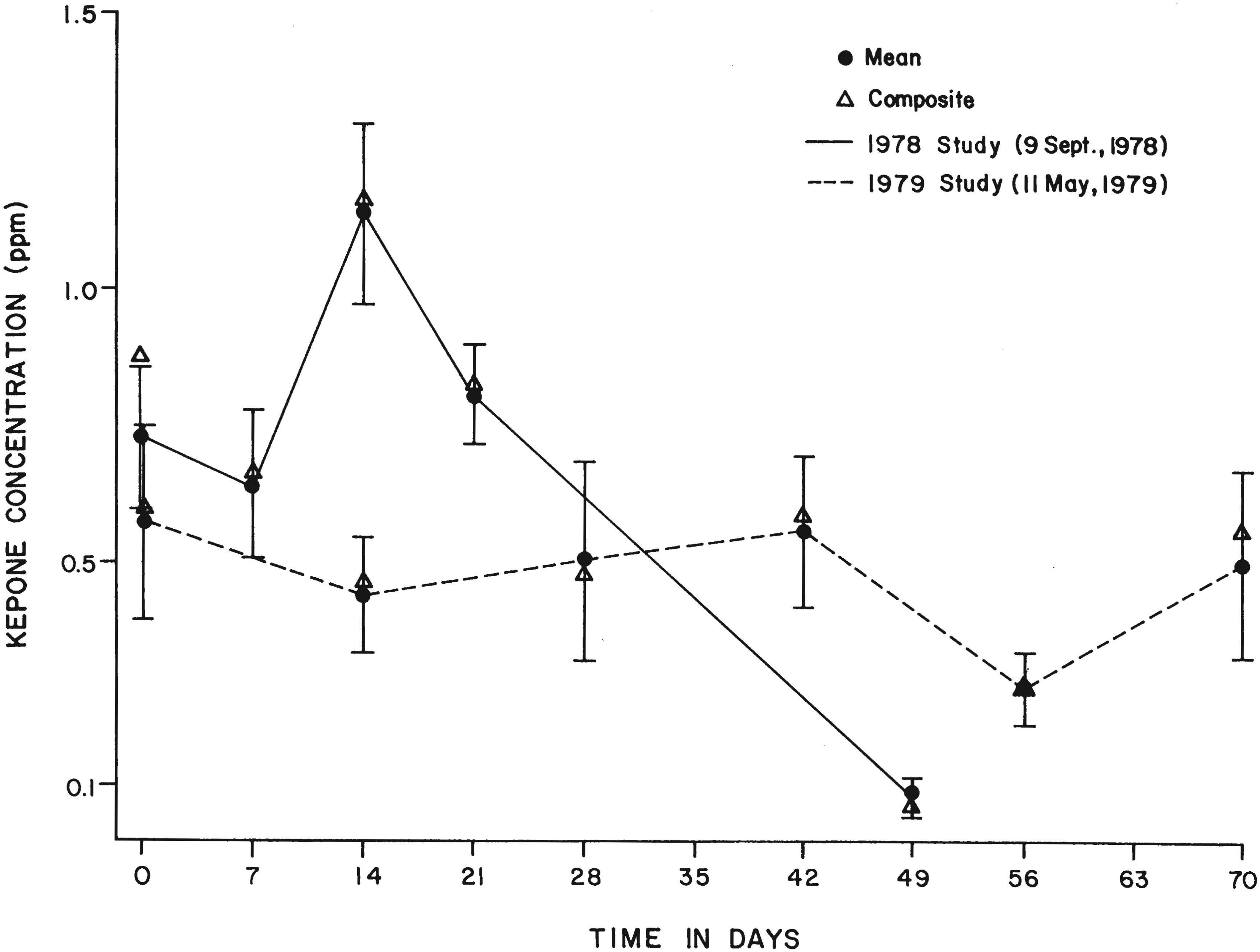
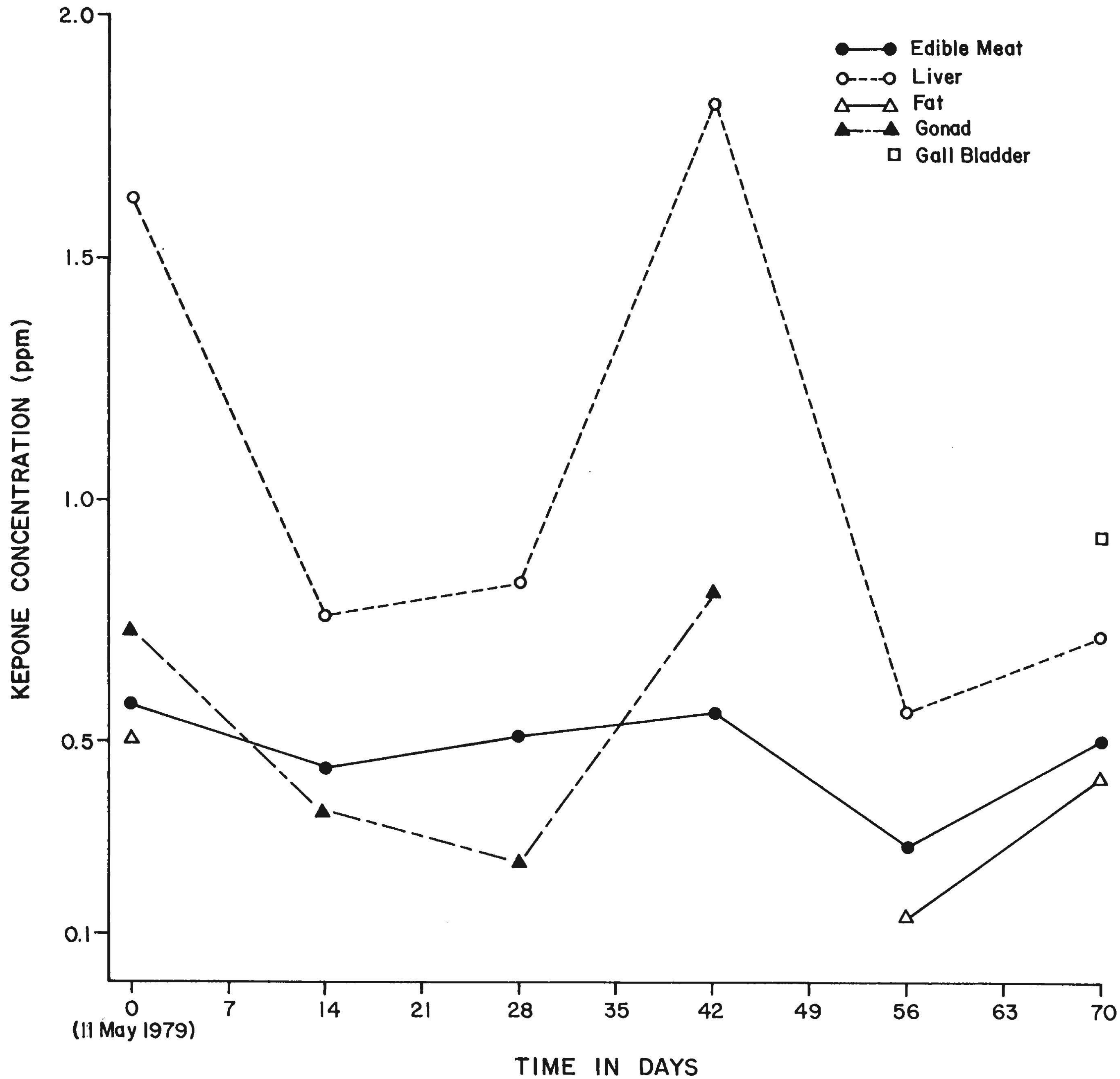


Figure 3. Distribution of Kepone in tissues of American eels in the 1979 study.



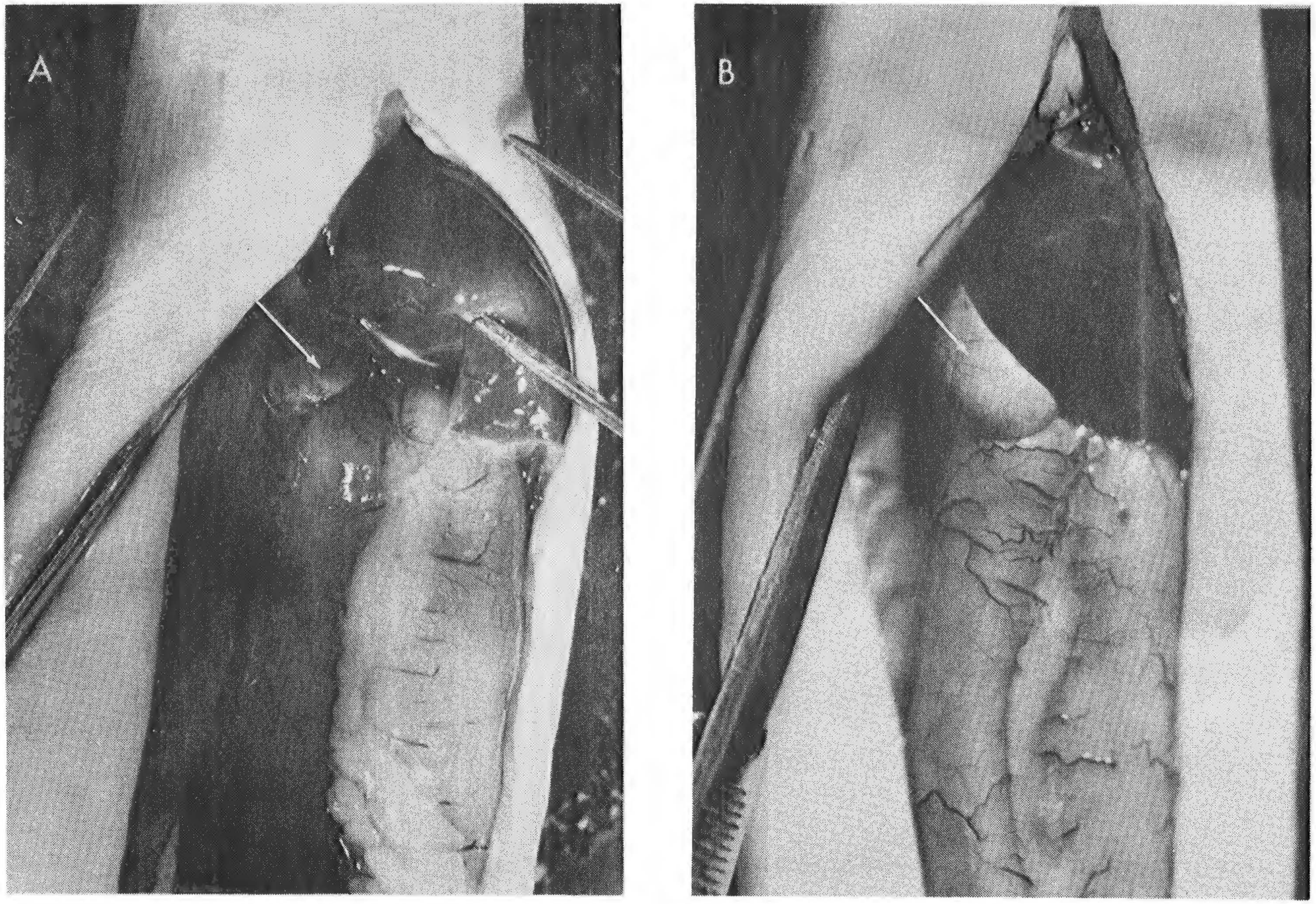


Figure 4. A. The normal appearance of the gallbladder in an American eel collected from the Rappahannock River. B. Gallbladder enlargement in an American eel from the day 70 sample.

Figure 5. Kepone effluent levels as observed from the uptake of Kepone by Rangia placed in an aquarium receiving water from the eel tank along with Kepone levels observed in edible meat samples of the eels.

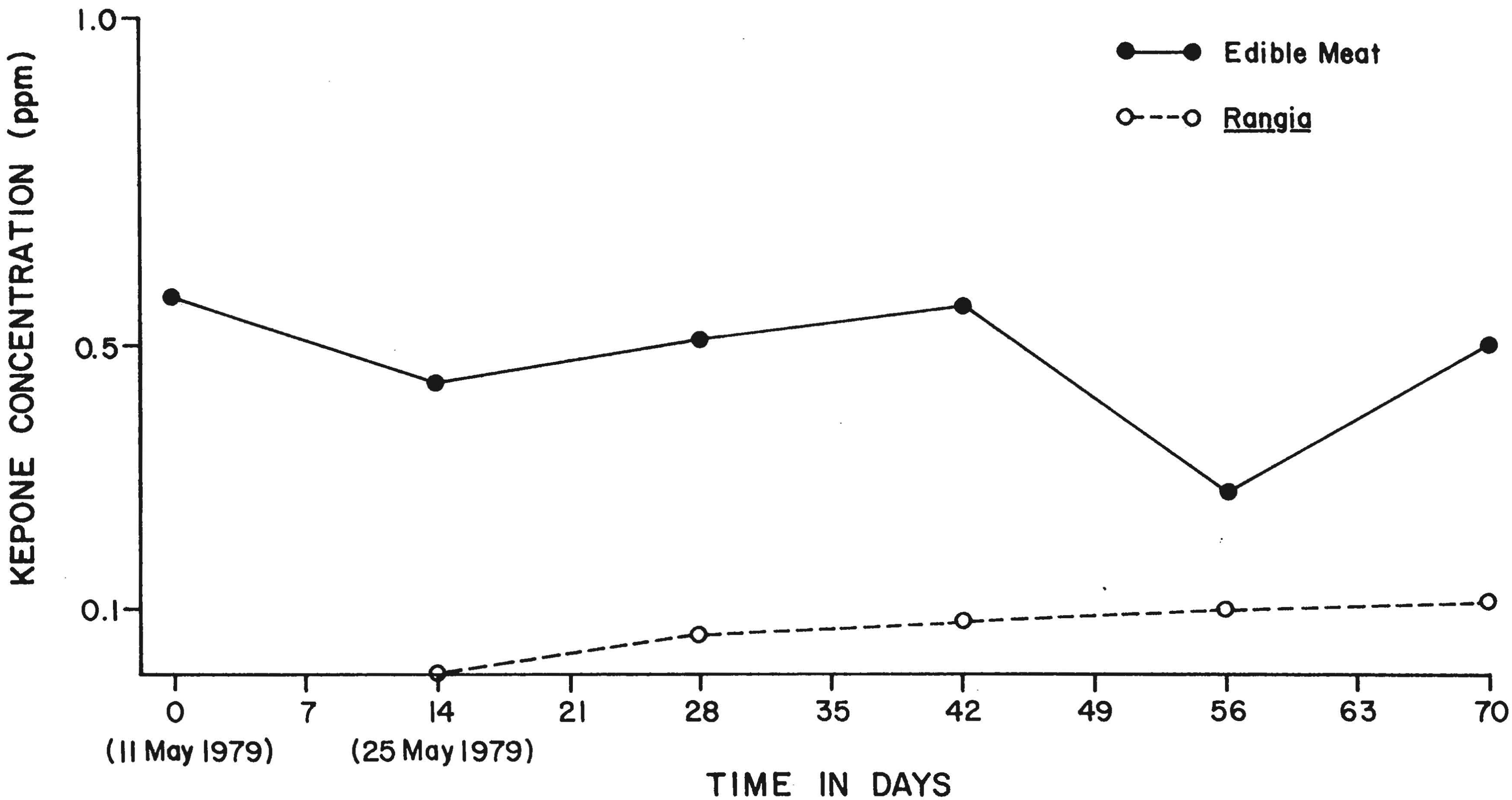


Table 1. Kepone concentrations (ppm) in American eels of the 1978 and 1979 studies.

	TIME IN DAYS								
	0	7	14	21	28	42	49	56	70
1978 Study									
Edible meat									
mean	0.728	0.643	1.134	0.808			0.080		
range	0.43-1.09	0.26-0.97	0.65-1.52	0.68-1.08	-	-	0.04-0.25	-	-
Composite (meat)	0.88	0.67	1.15	0.83	-	-	0.07	-	-
Liver									
mean							2.82		
range	-	-	-	-	-	-	1.54-3.65	-	-
1979 Study									
Edible meat									
mean	0.575		0.445		0.509	0.559		0.277	0.499
range	0.37-1.14	-	0.18-0.73	-	0.34-1.21	0.20-0.91	-	0.17-0.49	0.19-0.99
Composite (meat)	0.60	-	0.47	-	0.49	0.59	-	0.28	0.56
Liver									
mean	1.620		0.763		0.829	1.819		0.562	0.718
range	0.26-6.0	-	0.25-2.08	-	0.16-1.87	0.36-5.1	-	0.09-1.25	0.23-1.79
Composite (fat)	0.51	-	-	-	-	-	-	0.13	0.42
Composite (gonad)	0.730	-	0.350	-	0.250	0.812	-	-	-

Table 2. Average size and age of the American eels used in the studies.

1978 Study

Day	Mean Length (mm.)	Mean weight (gms.)	Mean age
0	464	204	6
7	480	212	8
14	482	227	7
21	493	224	8
49	485	216	9

1979 Study

Day	Mean Length (mm.)	Mean weight (gms.)	Mean age
0	526	277	9
14	484	208	8
28	489	205	8
42	500	253	8
56	452	169	7
70	508	212	8

Table 3. A one way analysis of variance of Kepone concentration in the edible meat samples over time (in days).

ANALYSIS OF VARIANCE					
Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	5.8636	1.4659	39.714	0.0000
Within Groups	45	1.6610	0.0369		
Total	49	7.5246			

Student-Newman-Keuls Test

Homogenous Subsets

Subset 1

Day	49
Mean	0.0800

Subset 2

Day	07	0	21
Mean	0.6430	0.7300	0.8080

Subset 3

Day	14
Mean	1.1340

PART II.

An Economic Analysis of the Commercial Depuration of Kepone Contaminated American Eels, *Anguilla rostrata* from the James River, Virginia

by

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July 31, 1979

TABLE OF CONTENTS PAGE

LIST OF FIGURES

LIST OF TABLES

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This analysis was conducted at the Virginia Institute of Marine Science with financial support received through the Commonwealth of Virginia from funds endowed to the state by Allied Chemical, Inc. for the purposes of Kepone research.

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INTRODUCTION

Life History of the American Eel

The American eel, *Anguilla rostrata*, is a catadromous species of fish, living in fresh water and going to sea to spawn.[1] Although no sexually mature male or female has yet been found there, eels are believed to spawn in the southwest North Atlantic Ocean in the region of the Sargasso Sea (Figure 1).[2] The eggs of *A. rostrata* develop into transparent larvae called leptocephali.[3] As the larvae develop over the course of their first year, they move to the upper water layers where ocean currents carry them to the coast of North America.[4] They then metamorphose into elvers or "glass eels" (Figure 2).[5]

During the months of January to May elvers arrive in the Chesapeake Bay.[6] Many elvers mature in coastal and estuarine habitats, while the remaining elvers migrate into fresh water.[7] Females are usually those eels found in freshwater while males apparently remain in brackish or saltwater.[8] Having occupied these habitats, the elvers begin to mature and are called "yellow eels."[9] Yellow eels usually remain in freshwater from five to ten years, although ages up to twenty years have been reported.[10] Each year, from late August through mid-November, the larger and older yellow eels which have developed into sexually mature "silver eels" migrate downstream toward the sea.[11] It is believed that they are guided by electro-navigation back to the Sargasso Sea where they spawn and die; no adults have been found returning to the coast.[12]

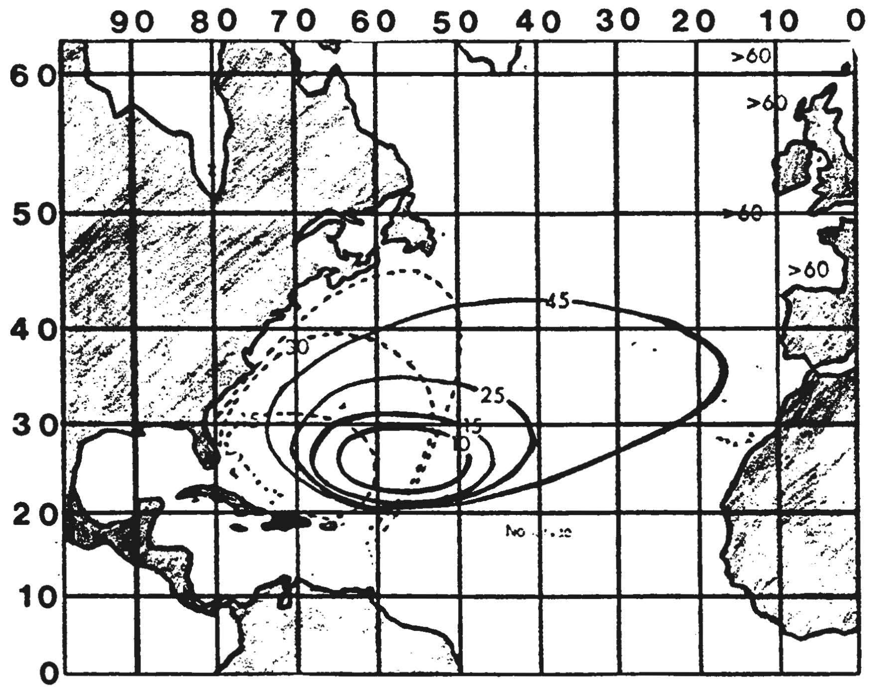


Figure 1. Location of the breeding areas of European and American eels. The distribution of larvae is shown by curves, continuous for the European species, dotted for the American. The heavily drawn inmost curves embrace the breeding areas of the two species and other curves show limits of occurrence; for example, specimens of less than 25 mm in length have been found only inside the 25-mm curve. Redrawn from Schmidt (1924).

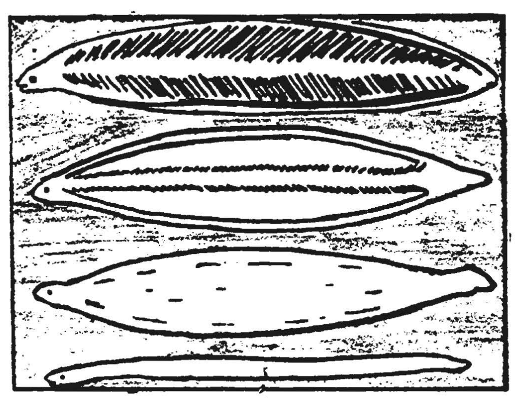


Figure 2. American eel, <u>Anguilla rostrata</u>. Metamorphosis of larvae. The top specimen is a full-grown larvae before metamorphosis, the lower one an elver. Gulf stream area off the Atlantic Coast of the United States. (Natural size. From Johs. Schmidt l.c. 1916)

World Market for Eels

In the past five years, the eel industry in the United States has increased dramatically.[13] This is a direct result of the expanding demand for eels and their contracting natural populations in Europe and Japan, the two areas from which most of the demand for eels for human consumption originates.[14] David M. Forrest, in his book, Eel Capture, Culture, Processing and Marketing (1976), reports diminishing weights of wild eels caught in Europe and a similar, although much more rapid phenomenon in Japan in recent years (Table 1).[15] At the same time that natural supply in these areas has been diminishing, the price per pound for eels has been rapidly increasing; in Europe, price per pound rose from an average of $1.02 in 1971 to $3-4 in 1977.[16] A lack of historical data from Japan precludes a similar comparison for that country; however, live eel prices in Japanese markets ranged from $4 to $6 per pound in 1977.[17] From these admittedly crude figures it can be inferred that demand for eels in Europe and Japan is increasingly in excess of supply, bringing higher prices to eel capturers. These higher prices, in turn, enable North American exporters to earn a positive return over shipping costs thereby opening the fisheries on the East Coast to the exporting of eels. The data in Table 2, compiled by Easley and Freund (1977), shows the margin that an operator on the mid-Atlantic Coast could expect from the sale of exported eels at different foreign price levels.[18] It is this potential for profit which makes development of the North American eel fishery, and especially that in Virginia, particularly attractive.

Table 1.

A. European eel

- Weight of European eels caught (1969-1974)

Country/year	1969	1970	1971	1972	1973	1974
Denmark	3.7	3.4	3.2	3.3	3.6	2.9
France	1.9	4.2	4.9	2.6	3.9	2.5
Germany (Fed.)	0.5	0.5	0.5	0.4	0.4	0.4
Germany (Dem.)	1.0	1.1	0.8	0.9	0.9	0.9
S. Ireland	0.1	0.2	0.1	0.1	0.1	0.1
Italy	3.4	3.2	3.3	2.8	2.9	2.7
Netherlands	2.8	1.5	1.2	1.1	1.1	1.0
Norway	0.5	0.4	0.4	0.4	0.4	0.4
Poland	1.1	1.0	0.9	0.9	0.8	0.9
Spain	1.5	1.2	1.2	1.5	1.2	3.6
Sweden	1.7	1.2	1.4	1.2	1.1	1.0
England and Wales	0.0	0.0	0.0	0.0	0.0	0.0
N Ireland	0.6	0.8	0.8	0.7	0.8	0.8
Russia	0.5	0.6	0.6	0.6	1.1	1.2
Morocco	0.0	0.0	0.0	0.0	0.0	0.0
Tunisia	0.1	0.1	0.1	0.1	0.8	0.3
TOTAL	19.4	19.4	19.4	16.6	19.1	18.7

B. Japanese Eel

Weight of Japanese wild eels caught (1969 1974)

Country/Year	1969	1970	1971	1972	1973	1974
Taiwan	1.6	2.0	3.9	—	—	—
Japan	3.2	2.7	2.6	2.4	2.4	2.1
Korea	0.4	0.1	0.2	0.1	0.1	0.1
TOTAL	5.2	4.8	6.7	2.5	2.5	2.2

Table 2.

Market Prices Less Air Freight Rates for Two Weight Classes.

Market	Price	Less Effective Freight Rate*	Net Price
		(dollars per pound)	
Europe (Rotterdam)	4.00	1.49	2.51
		1.08	2.92
	3.50	1.49	2.01
		1.08	2.42
	3.00	1.49	1.51
		1.08	1.92
Japan (Osaka)	6.00	2.55	3.45
		2.03	3.97
	5.00	2.55	2.45
		2.03	2.97
	4.00	2.55	1.45
		2.03	1.97

*Effective rate applies to cost per pound of eel actually shipped. Live shipping requires holding tanks and water or misting system. It is assumed that the tanks, etc., account for 25 percent of weight shipped; hence, the effective rate is the quoted rate divided by 75 percent.

Virginia Eel Fishery

The eel fishery in Virginia is composed primarily of potting for grown, wild eels in estuaries and streams.[19] Following the trend of the rest of North America, Virginia Landings of eels have only recently become appreciable. The data arrayed in Appendix I shows reported poundage and dollar value for the thirteen years proceeding the 1975 closing of the James River due to Kepone contamination. The estimates are probably low since most transactions are made in cash and cannot be monitored by the National Marine Fisheries Service, which collected the data.[20]

Prior to 1973 the value of Virginia eels for export for human consumption was not widely realized.[21] Until that time eels were caught primarily for bait.[22] Other than this limited market value, they were considered a nuisance by fishermen to whose lines the fish would often become attached. Forrest (1974) offers the following explanation for the low annual poundage of eels landed in North America based on 1974 data:

> The total quantity of wild American eels captured is negligible by comparison with the figures for the European eel and has been static for a number of years at, or around 2,000 tons annually. There are some experts who believe this species of wild eel is still largely unexploited. This is perhaps due to both a lack of interest and hence demand from the home market, as well as only relatively few fisherman being trained in eel capture, because other types of occupation offer considerably better incomes. It is partly because of the lack of demand in North America that a number of attempts over the years have been made to export live American eels and elvers to Europe and the Far East.

> The weakness of their competitive position in comparison to the locally caught wild eels and the low profitability of such an operation, once air freight charges have been taken into consideration, limits the spread of American eel exports on a larger scale except for a few days at a time each year when, perhaps, market conditions are favourable. Some exports have been attempted by sea-shipment.[23]

In Virginia it is estimated that current annual landings of adult eels probably exceed one million pounds, which are valued at approximately one-half million dollars.[24] Although the large migrating silver eels caught in the fall can bring a fishermen up to $1.25 per pound, the yellow eels more commonly caught in the brackish and freshwater of Tidewater Rivers have averaged fifty cents per pound in value.[25] According to several fishermen, however, this estimate is too low; prices have ranged upwards of one dollar per pound with an average closer to eighty cents per pound.[26] Given the increasing number of live-tank truck operators, who actually ship the eels to overseas markets or sell to processors that do, a rise in price is not peculiar.[27] Private market operations would tend to benefit suppliers when an increasing number of buyers begin to compete for their product. In this case the suppliers are fishermen, their product is eel and the buyers are live-tank truck operators; the operation is similar to the factor market for labor in that the eels, like labor services, represent a resource and the suppliers usually outnumber the buyers. Just as an increase in the demand for labor services on the part of employers leads to an increase in the wage received by workers, so an increased number of live-tank truck operators demanding collectively more eels should lead to an increase in the price received for them by fishermen.

The eel fishery in Virginia is presently underexploited. In Europe and Japan, eel fishing is either rapidly approaching or has already passed maximum sustainable biological yield.[28] The continued expansion in these markets of the demand for eels beyond their limited biological supply, combined with the favorable terms of trade which characterize the export of eels from eastern North America into these markets, make expansion of the eel fishery on the East Coast attractive.[29]

To a large extent, however, exploitation of the Virginia eel fishery has been precluded by the closing of the James River to the taking of fish for consumption in 1975. At that time, relatively high concentrations of Kepone, a pesticide discharged with the effluent from a Hopewell chemical plant, were found present in fish taken from the river.[30]

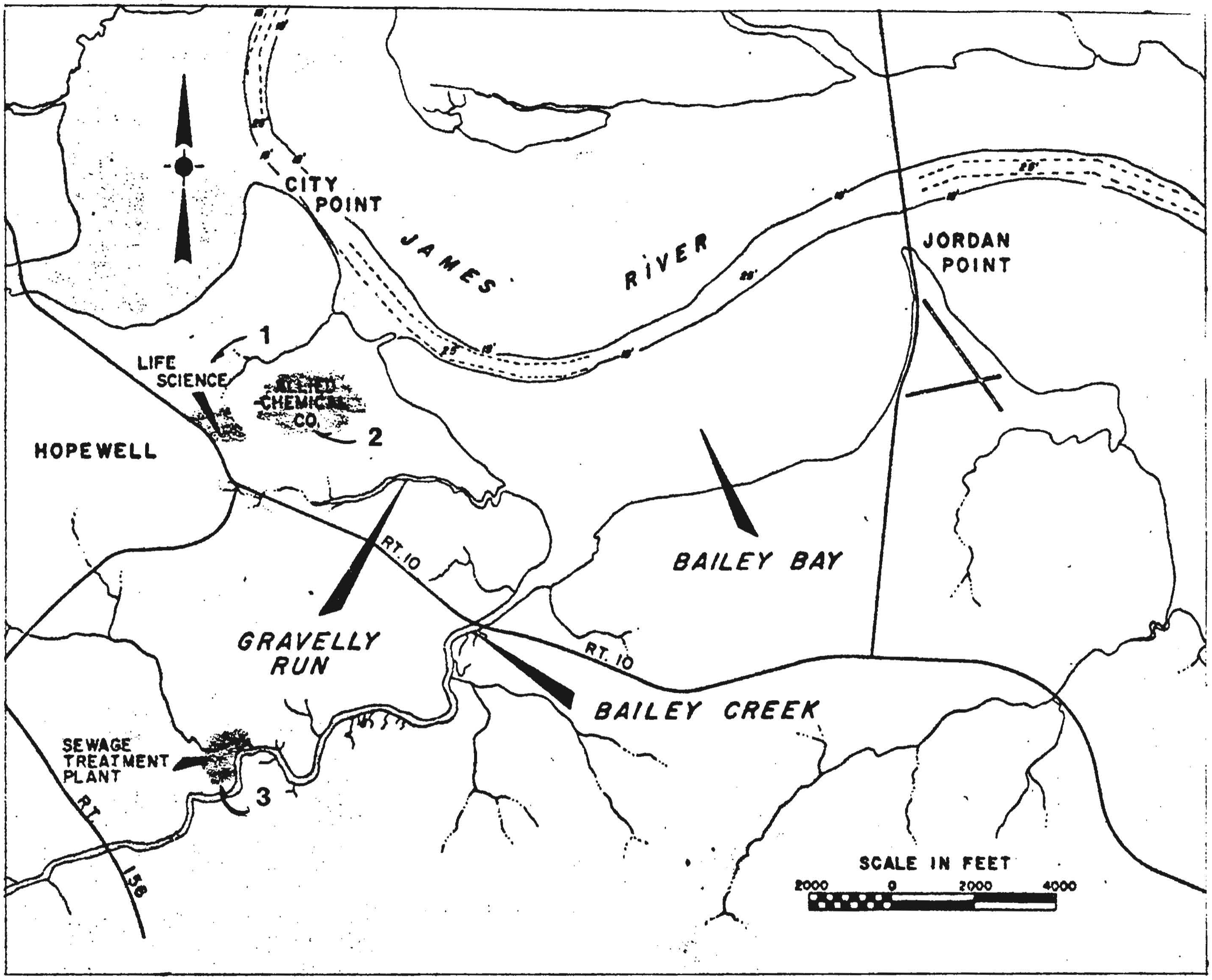
The Kepone Problem

Kepone is the tradename for Chlordecone, a pesticide.[31] It was discharged from two manufacturing operations around Hopewell, Virginia from 1966 to 1975 (see Figure 3).[32] The Semi-Works Plant of the Allied Chemical Corporation produced Kepone intermitently from 1966 to 1974 (Numeral 1 in Figure 3); from 1974 until its closure in September of 1975, Life Science Products Company produced Kepone under contract to Allied Chemical (Numeral 2 in Figure 3).[33]

As a result of the manufacturing process, it is estimated that 150 pounds of Kepone were released into the air each day, most of which settled on surface soils.[34] Waste water from the plant containing the chemical was discharged into the sewage system and passed through the Hopewell Sewage Treatment Plant, into Bailey Creek, and on into the James River (Numeral 3 in Figure 3). Analyses indicated that water and seafood in the river below the city had been contaminated by Kepone.[35]

Kepone is apparently neither bio-degradable nor readily soluable in water; its degree of solubility depends on the alkaline level of the water.[36] This persistence in the environment is aggravated by the fact that authorities do not know what concentration of Kepone, if any, is acceptable in the environment.[37] Persuant to recommendations made by the United States Environmental Protection Agency the U.S. Food and Drug Administration has established the following action levels for Kepone in the edible portions of finfish, shellfish, and crabs as acceptable levels of safety for human consumption:[38]

Figure 3.


CITY
POINT
JAMES
RIVER
JORDAN
POINT
1
LIFE
SCIENCE
ALLIED
CHEMICAL
CO.
2
HOPEWELL
BAILEY BAY
RT. 10
GRAVELLY
RUN
RT. 10
BAILEY CREEK
SEWAGE
TREATMENT
PLANT
3
RT. 156
SCALE IN FEET
2000
0
2000
4000

	Parts Per Million (PPM)
Finfish	0.3
Shellfish (clams, mussels, oysters)	0.3
Crabs	0.4

These levels were based on estimated consumption levels of various species and types of seafood.[39]

Kepone poisoning is rare and is therefore not well-described in medical literature.[40] The chemical concentrates in the liver and body fat and has been implicated by the National Cancer Institute as a cancer-causing agent in laboratory animals.[41] What remains unknown are the long-term effects of Kepone on the human body, how much is required to produce symptoms and how, or even whether the body rids itself of the chemical.[42] Because of the large number of unknown factors involved, the U.S. Environmental Protection Agency does not recommend that clean-up action be undertaken on the James River.[43]

Since the Virginia State Board of Health issued the Emergency Rule on 18 December, 1975, "Closing of the James River and Its Tributaries to the Taking Fish," it has opened the river to the taking of some species of fish with acceptable levels of Kepone and/or minimal use for human consumption subsequent to gubernatorial authorization. These species include the following: catfish, female hard crabs from the lower James River, shad, herring and turtles.[44] In June, 1979, Governor Dalton lifted the ban on male crabs in the Lynnhaven River, Lynnhaven Bay, Broad Bay Linkhorn Bay areas of Virginia Beach. The American eel, because of its high fat content, contains a high concentration of Kepone. The 1975 level was estimated at 0.64 parts per million.[45]

An estimate of the income loss to eel fishermen based on reported poundage and dollar value of eels caught in the James and Chickahominy rivers in 1975 approximates $45,000; using even the present average market price (estimated at fifty cents per pound) total losses would not top $60,000 (see Appendix I)[46] According to all four fisherman interviewed, only two of whom were relying on the James River for income in 1975, the river and its tributaries have traditionally been better-stocked with eels than either the York or Rappahannock rivers.[47] No scientific data exist to support or refute these statements; however, their concurrence in separate interviews is noteworthy. The two James River fishermen interviewed gave conservative estimates of approximately 1,000 pounds per week of eels they were catching unintentionally in their catfish pots.[48] This, of course, had to be returned to the river; it is unreliable to use in computing income loss since it is an accidental catch.

The most reliable estimate of income loss to James River fishermen due to the prohibition on eel fishing is to estimate what income a fisherman must forego because of the ban. This is based on the estimated poundage of eels a fishermen will catch for a given amount of fishing effort and the estimated price per pound he would receive by selling the eels to a live-tank truck operator. From this, an estimate of income foregone is subtracted from the income the fisherman receives from employing his resources in their next best alternative use; if he continues fishing on the James River his options are limited to fishing for catfish, shad or herring.[49] The results for one week are outlined below (poundage is held constant as a proxy for fishing effort).[50]

		Value
(a)	Eel catch foregone: 2,000 lbs. @ $0.50	$1,000
(b)	Next best catch:[51] 2,000 lbs. @ $0.25	500
(c)	Estimated income loss: (a-b)	500

Granted, the analysis is rough at best; but, it points to potentially heavy losses to James River fishermen as a result of the ban on eel fishing.

Purpose of Study

In a preliminary study conducted at the Virginia Institute of Marine Science during the fall of 1978, a sample of fifty eels was taken from the James River and placed in water uncontaminated by Kepone.[52] After a period of forty-nine days the fish were found to contain significantly lower concentrations of Kepone which were below the revised level established by the United States Food and Drug Administration in 1977.[53]

During this time the eels did not feed; however, eels have been starved up to 145 days with only a 21 percent loss of body weight.[54] Most fishermen, in fact routinely hold eels without feeding from 2 to 12 weeks while waiting for their market price to rise or for enough to be captured to fill their holding trucks.[55]

Based on these findings, and in light of the substantial additional income James River fishermen could potentially reap by harvesting eels, an economic analysis of the costs of depuration viś-a-viś its benefits was undertaken to determine if it could feasibly be conducted on a commercial scale. This is the analysis that follows.

Depuration refers generally to the purification process without defining initial or final conditions.[56] The initial condition of James River eels is characterized by a concentration of Kepone which the U.S. Environmental Protection Agency has declared potentially hazardous to human health if consumed.[57] The final condition of these eels after depuration, based on the findings of the preliminary study, is characterized by a Kepone concentration not considered hazardous if consumed according to the same set of standards.

This analysis is based on the depuration studies outlined in Part I. It is an economic analysis of conducting depuration on a commercial scale. It is presented with the goal of opening a door for James River fishermen to again earn income from its waters.

METHODS OF ANALYSIS

To provide a method to analyze the economic feasibility of conducting depuration on a commercial scale for an individual James River fisherman a worksheet was constructed. A sample worksheet is presented in Appendix II. It is a version of an "eel fishing enterprise worksheet," created by L. Abbas as part of An Economic Analysis of A Part-Time Eel Fishing Enterprise (1977), and modified for a full-time enterprise conducting depuration.[58] To understand the nature of both eel fishing and the eel market, interviews were conducted with four Tidewater fishermen.

For the purposes of this analysis, it is assumed that fishermen will be required to purchase a special license permitting the taking of eels from the James River for human consumption. It is acknowledged that before such a license could be granted, the Emergency Rule of the Virginia State Board of Health of 1 January 1978, "Prohibiting the Taking of Crabs and Fish from the James River and Its Tributaries", would have to be revised.[59] It is further assumed, however, that such action would not be hindered once net benefits in excess of the costs of eel fishing for depuration were exhibited, but would be forth coming in a manner similar to the lifting of restrictions on shad and herring fishing from the James River in 1977, when evidence of acceptable Kepone levels in these fish was presented to the governor.[60]

To enter the eel fishery requires investment in such equipment as a boat, motor, truck and eel pots.[61] Miscellaneous equipment, such as dip nets, pails, ropes and grappling hooks is also required.[62] Only one of the four fishermen interviewed uses a depth finder; however, one is included in the calculation of investment since it is considered important by other authorities, as well.[63] A freezer in which bait is stored is also included.

To conduct depuration requires a separate freshwater holding facility for each week's catch of eels. Stocking density is assumed to be 0.8 pounds per gallon.[64] Since it was determined from interviews with fishermen that an average of 2,000 pounds of eels could be caught per week this is the amount assumed to be depurated at one time.[65] Accordingly, the facilities considered in this analysis include separate holding tanks for eight weeks' catches.

Oxygen demand between temperatures of 62.8°F and 71.6°F is 0.019835 cubic inches per pound to 0.026298 cubic inches per pound each minute.[66] To meet this requires an air compresser of 1/3 horsepower.[67]

The water system must be capable of supplying four gallons per minute to each tank.[68] While the main lines are probably more sturdy if rigid, the tank input lines should be flexible to allow the flow rate to be checked. Although somewhat more costly, a valve on each input line greatly facilitates tank cleaning.

A shelter is also included in calculating investment since the protection from direct sunlight it affords keeps water temperature and, therefore, oxygen demand low. The shelter also helps extend the economic life of the tanks and the water and aeration systems.

Annual costs are divided in the worksheet between fixed and variable costs. A figure examining the interest foregone on the investment capital is included in calculating the fixed cost to account for the opportunity cost of investing those funds in eel fishing rather than in their next best alternative use.

This analysis is not based on the data collected from any one fisherman. Its purpose, rather, is two-fold; it attempts to estimate figures for the average James River fisherman while at the same time providing an example for individual fishermen to follow in computing the feasibility of conducting depuration in their own specified circumstances. Once the labor requirements and total receipts for this average fisherman were estimated, in addition to the information introduced above, the net return that an average fishermen could expect was calculated. Individual fishermen should use the sample worksheet in Appendix II to analyze their own expected return before attempting to conduct depuration on a commercial scale.

RESULTS

Investment

Since most James River fishermen already own a boat, motor and truck, these items are listed at market value.[69] A new entrant to the eel fishery, however, should list all items bought at cost. The market value of an investment item already owned represents non-monetary investment; its employment in eel fishing precludes its use in another occupation.

Most eel pots are cylindrical and four feet long with an average catch of 5-6 pounds each day.[70] A charge for labor is imputed in the cost of the pots. The freezer is assumed to be used.

Although PVC plumbing is expensive it is probably most desirable for use in depurating eels that will be consumed by humans. The estimate for the well is also an imputed market value since most fishermen have an artesian well with the necessary pumping capacity at their use.[71] Finally, most fishermen indicated they would fish approximately 50 pots.

ITEM	VALUE
Boat (22')	$ 3,000
Motor (140 HP outboard)	1,000
Truck (Ford F-150)	3,000
Eel Pots: 50 @ $40[73]	2,000
Freezer	100
Miscellaneous[74]	100
Depth Finder[75]	100
Tanks (see Appendix III)	960
Shelter (see Appendix IV)	5,917.05
Aeration System (see Appendix V)	240
Water System (see Appendix V)	2,419.50
TOTAL INVESTMENT:	$19,886.55

Fixed Cost Per Year

Fixed costs occur whether fishing is done or not. Although it is a fixed cost, few fishermen have been observed to insure their fishing equipment.[76] The largest fixed cost component, depreciation, is calculated by dividing the value of the asset by its life. For previously-owned investment items the expected life is assumed to be one-half what it was at purchase. Expected life of eel pots is based on interviews with fishermen. Expected life of newly acquired investment items is listed as if it were new.

ITEM	LIFE (YEARS)	VALUE
Depreciation		
Boat	(5)	$ 600
Motor	(2)	500
Truck	(5)	600
Freezer	(5)	20
Depth Finder	(5)	20
Eel Pots 50 @ $10	(4)	500
Tanks 8 @ $24	(5)	192
Shelter	(10)	591.70
Air Compressor	(5)	20
Interest on Investment: (.12 X Value of investment)		2,386.39
Taxes and Insurance (.02 X Value of investment)		397.73
Commercial Fishing License[77]		13
TOTAL FIXED COST:		$5,840.82

Variable Cost Per Year

Variable costs occur when fishing is actually taking place. The eel fishing season is usually 13 weeks in both the spring and the fall for a total of 26 weeks each year.[78] Interviews with fishermen revealed average driving of 20 miles per day associated with fishing, although this figure is variable depending upon proximity of residence to the James River.[79]

Chemicals needed include acetone with which to clean the tanks of Kepone residue and Tetramyacin for pretreating the eels against bacterial infections.

Labor requirements are a hybrid of the expected labor requirements given in interviews. The hourly wage rate, however, is fairly uniform.[80]

Pursuant to the granting of a special license to fish for eels on the James River, it is assumed that representative samples of eels during weeks' 6-10 of depuration would have to be analyzed for Kepone concentration by an authorized agent of the Virginia State Board of Health before it could be released for sale. One result of the initial depuration study was that composite sampling was found to be as valid a representation of Kepone concentration as simple random sampling.[81] Kepone analysis would therfore not be a prohibitively costly means of enforcement.

ITEM	VALUE
Vehicle: 3,640 Miles @ 15¢	$ 546
Boat and Motor Operation: Gas, Oil, Etc. [82]	273
Boat and Motor Maintenance (.05 X Value)	150
Eel Pot Maintenance (.05 X Value)	100
Eel Pot Replacement (.25 X Value)	500
Shelter, Tank, Aeration and Water Systems Maintenance (.05 X Value)	386
Bait[83]	1,092
Tank Replacement (.135 X Value)	130
Chemicals[84]	200
Electricity (lights, sockets, and freezer)	50
Labor: 1 full-time employee[85]	4,639
1 part-time employee[86]	2,318
Kepone Analysis: 26 wks. @ $50[87]	1,300
TOTAL VARIABLE COST	$11,687

Labor Requirement

It is esimtated that the fisherman will spend 56 hours per week for the 26 weeks of the eel fishing season operating his enterprise. For the seven weeks after the end of each 13-week run during which the last of the eels are depurating, it is assumed he will spend 2 hours per day involved with the eel fishing enterprise. Hours per year needed to operate enterprise: 1,652.

Receipts

The market price is conservatively estimated to average 50 cents per pound. With an average catch of 2,000 pounds per week for 26 weeks the receipts are as follows:

TOTAL: 52,000 pounds @ 50¢ $26,000

Summary

Subtracting total costs from total receipts leaves the net return to the fisherman. This, in turn gives the return to labor and management and the return to investment. The net return less the amount the investment could have earned in another use is the return to management. The net return less the amount the operator could have earned by employing his labor elsewhere is the return to investment.

The break-even catch is the poundage and the break-even price is the price per pound at which total costs are just covered, assuming 50 pots are still being fished.

Total Receipts	$26,000.00
- Total Cost	17,527.82
Net return to labor, management and investment	8,472.18
Return to labor and management (net return-.12 X Value of investment)	6,085.79
Return to investment (net return - $3 X labor requirement)	3,516.18
Percent return to investment (return to investment ÷ investment)	17.68
Break-even catch per year (total cost ÷ price/lb.)	35,055.64 lb.
Break-even price (total cost ÷ estimated catch)	33.7 ¢

CONCLUSION

The average James River fisherman can expect to cover all the costs of conducting depuration on a commercial scale and still earn a greater than 17 percent return on his investment. This translates into an excess of net benefits associated with depuration over its costs. Of course, as the investment is increased with, for example, fiberglass culture tanks or race-ways and an enclosed facility, this percentage return will fall. It is also important to remember that the percentage return is only an indicator of profitability, not an absolute standard, and only has significance relative to the rate of return being offered by other investments. 17.68 percent, however, is a high yield by almost any standard. It cannot be over-stressed how important it is for individual fishermen to compute their own rate of return.

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[54] Aake Larsson and Kerstin Lewander, "Metabolic Effects of Starvation in the Eel, Anguilla Anguilla L."; IN: Comparative Biochemical Physiology; (Great Britain, Pergamon Press) 1973; Vol. 44A, p. 368.

[55] Information obtained in interviews with Mr. Haynes and Mr. Ira Williams.

[56] Bruce J. Neilson, et. al., Bacterial Depuration by the American Oyster Under Controlled Conditions; (Gloucester Point, VA; VIMS) May, 1978; Vol. II, p. 4.

[57] Kenley, p. 1.

[58] Leon E. Abbas, To Eel or Not to Eel; (Raleigh, NC; Sea Grant) February, 1977; p. A.

[59] Kenley, p. 3.

[60] Ibid.

[61] Ibid., p. 2.

[62] Ibid.

[63] Ibid, p. 2.

[64] In: Fish Farming International (F.F.I. London) June, 1978

[65] Information obtained in interviews with four Tidewater fishermen

[66] Forrest, p. 73.

[67] Conde Milking Machine Co., Inc., Sherrill, N.Y. 13461; Price list 1976.

[68] Freund and Easley, p. 4.

[69] Information obtained in interviews with four Tidewater Fishermen.

[70] Ibid.

[71] Ibid.

[72] Ibid.

[73] Ibid.

[74] Abbas, p. 2.

[75] Ibid.

[76] Ibid., p. 3.

[77] Virginia Marine Resources Commission.

[78] Abbas, P. 4.

[79] In formation obtained in interviews with four Tidewater Fishermen.

[80] Ibid.

[81] Hedgepeth, p. 1.

[82] Based on information obtained during interviews with four Tidewater Fishermen, average water mileage logged each day is 10 miles.

[83] 2 lbs./pot/day X 50 pots X 182 days/yr. @ 6¢/lb.

[84] Freund and Easley, p. 14.

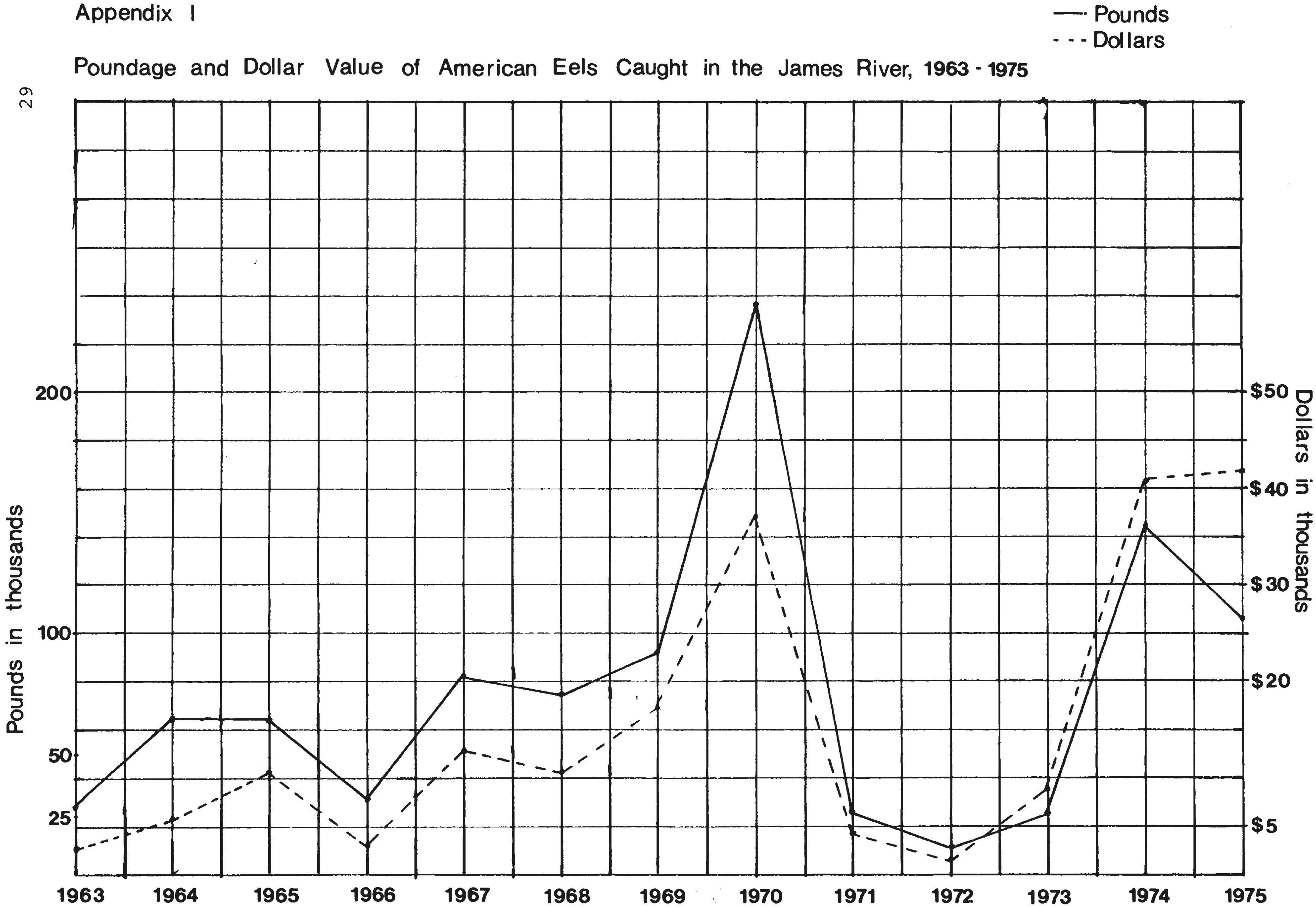
[85] 8 hrs./day X 182 days/yr. @ $3/hr. + .0613 FICA.

[86] 4 hrs./day X 182 days/yr. @ $3/hr. + .0613 FICA.

[87] Michael Bender, personal communique.

Appendix I

Poundage and Dollar Value of American Eels Caught in the James River, 1963 - 1975



APPENDIX II

Investment

Item		Value
Boat		$ ______
Motor		______
Truck		______
Eel pots: ____ @ $ ____		______
Freezer		______
Miscellaneous		______
Depth finder		______
Tanks: ____ @ $ ____		______
Shelter: ____ sq. ft. @ $ ____		______
Aeration system		
Hoses and micro-pore tubes	____ ft. @ $ ____	______
Air compressor	____ h.p.	______
Installation	____ hours @ $ ____	______
Water system		
Feeders, main	____ feet @ $ ____ (2" PVC)	______
Tank input lines	____ feet @ $ ____ (1" PVC)	______
Fittings	.15 X (above)	______
Valves	____ @ $ ____	______
Main tank drains	____ feet @ $ ____ (4" PVC)	______
Tank drains	____ feet @ $ ____ (1.5" PVC)	______
Fittings (drain)	.15 X (above)	______
Installation	____ hours @ $ ____	______
Well (4")	____ feet @ $ ____	______
(1) Add for total investment:		$ ______

FIXED COST PER YEAR

Item		Life (years)	Value
Depreciation			
Boat		( )	$ ______
Motor		( )	______
Truck		( )	______
Freezer		( )	______
Depth finder		( )	______
Eel pots:	____ @ $ ____	( )	______
Tanks:	____ @ $ ____	( )	______
Shelter		( )	______
Air compressor		( )	______
Interest on investment: (.12 X value of investment)			______
Taxes & Insurance (.02 X value of investment			______
Commercial fishing license			______
____________			______
____________			______
____________			______
____________			______
(2) Add for total fixed cost:			______

VARIABLE COST PER YEAR

Vehicle: ____ miles @ $ ____ $ __________

Boat and motor operation: gas, oil, etc. __________

Boat and motor maintenance __________

Eel pot maintenance __________

Eel pot replacement __________

Bait: ____ pounds @ $ ____ __________

Shelter, tank, aeration and water systems maintenance __________

Tank replacement __________

Chemicals __________

Electricity (lights, sockets, and freezer) __________

Labor: ____ full-time employee(s)

X____ hrs./day X ____ days/wek. X ____ wks./yr.

@ $ ____ __________

____ part-time employee(s)

X____ hrs./day X ____ days/wk. X ____ wks/yr.

@ $ ____ __________

Kepone analysis: ____ weeks @ $ ____ __________

______________ __________

______________ __________

______________ __________

______________ __________

(3) Add for total variable cost: __________

LABOR REQUIREMENT

(4) Hours per year needed to operate enterprise

____ wks. @ ____ hrs. ________hrs.

____ wks. @ ____ hrs. ________hrs.

RECEIPTS

(5) Total: ____ lbs. @ $ ____ $ __________

SUMMARY

(6) Total receipts (from line 5) $ __________

(7) Total cost (line 2 + line 3) $ __________

(8) Net return to labor, management and investment (line 6 - line 7) $ __________

(9) Return to labor and management (line 8 - .12 X line 1) $ __________

(10) Return to investment (line 8 - $2.90 X line 4) $ __________

(11) Percent return to investment (line 10 ÷ line 1) $ __________

(12) Break-even catch per year (line 7 ÷ price per pound of eels) __________lbs.

(13) Break-even price (line 7 ÷ estimated catch per year in lbs.) $ __________

APPENDIX III

Depuration Tank Type[1]	VALUE
Steel-walled swimming pool	$ 120.[2]
3' X 12' round	
Estimated Life: 5 years	
Fiberglass culture tank	$ 840.[3]
3' X 12' round	
Estimated Life: 10 years	
Fiberglass raceway	$1,330.[4]
3' X 5' X 19'	
Estimated Life: 10 years	

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[1]Capacity for all types is 2,500 gallons.

[2]Estimate is based on a recent bid to VIMS made by a national retailer.

[3]List price, Red-Ewald, Inc. P. O. Box 519, Karnes City, TX.

[4]Ibid.

APPENDIX IV

A) OPEN SIDED FACILITY

1.	Lumber:[1]		
	4" X 4" X 8'	37@ $ 4.60	$ 170.20
	2" X 4" X 16' (#2)	60@ $ 3.80	228.00
2.	Concrete:[2]		
	5 cu. ft. footings	37@ $26.50	980.50
3.	Fiberglass roofing:		
	26" X 96" panels	112@ $ 5.00	560.00
4.	Electricity (lights, sockets, and freezer)[3]		100.00
5.	Property[3]	3,750 sq. ft. @ 69¢	2,587.50
6.	Sales tax (VA = .04)		181.05
7.	Labor	160 hrs. @ $8	1,280.00
8.	TOTAL		$ 5,917.05

B) ENCLOSED FACILITY

1.	Concrete floor:	35 cu. yds. @ $38.50	$ 1,347.50
2.	Building (incl. labor):[4]	2,400 sq. ft. @ $5.00	12,000.00
3.	Property		2,587.50
4.	Electricity		100.00
5.	Sales tax (VA = .04)		641.40
6.	TOTAL		16,676.40

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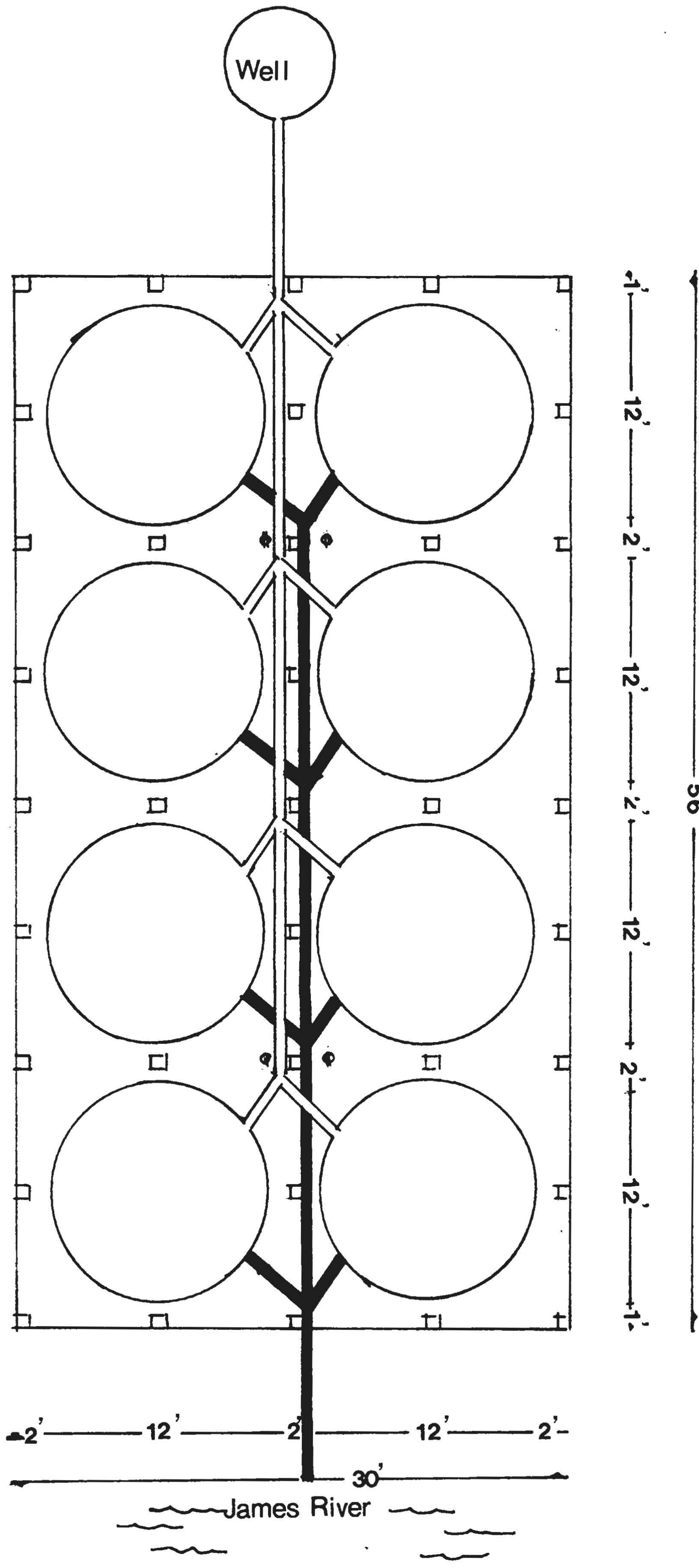
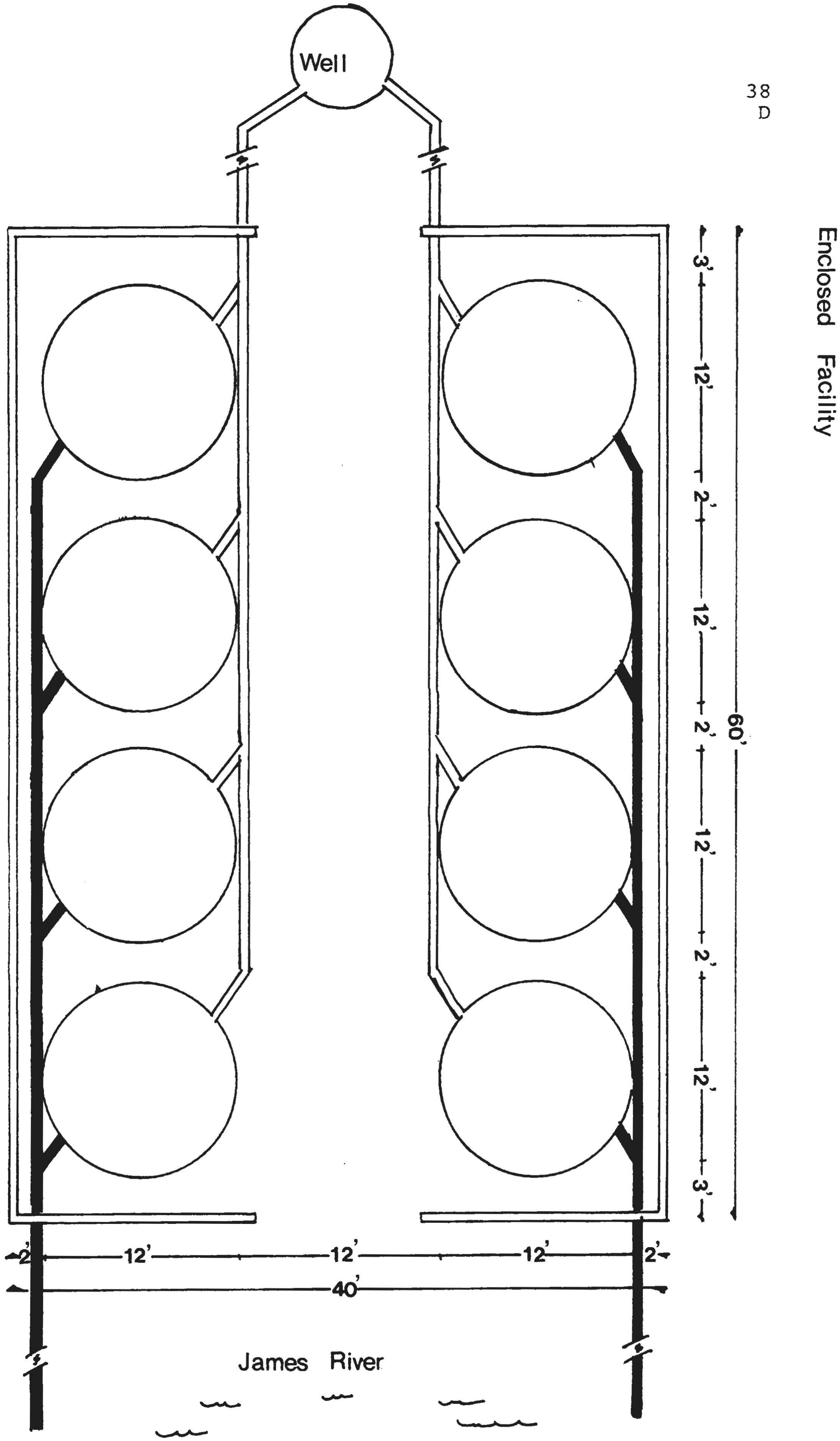
[1]Estimates for materials prices were obtained in telephone interviews with local suppliers.
[2]Estimates for concrete costs were obtained in telephone interviews with local suppliers
[3]Property values are based on an estimate of $30,000 per acre fronting on the James River which was obtained in a telephone interview with a Toano, Virginia realtor.
[4]Construction cost estimates were obtained in a telephone interview with a local commercial contractor.

C) ENCLOSED FACILITY FOR RACEWAYS

1.	Concrete floor	35 cu. yds. @$38.50	$ 1,347.50
2.	Building (inc. labor):	2,400 sq. ft. @$5.00	12,000.00
3.	Property	5,000 sq. ft. @ 69¢	3,450.00
4.	Electricity		100.00
5.	Sales tax (VA = .04)		675.90
6.	TOTAL		$17,572.95



Open - Sided Facility


Well
Enclosed Facility
3'
12'
2'
12'
2'
12'
2'
12'
3'
60'
2'
12'
12'
12'
2'
40'
James River

Enclosed Facility Equipped with Raceways